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PAINTING DEFECTS
Their Causes and Prevention

An Address by

G. W. THOMPSON

Chief Chemist, National Lead Co

Delivered at the Eleventh Annual Convention Maintenance of Way Master Painters' Association of the United States and Canada, November 18th, 1914, and at the Semi-Annual Meeting of the American Institute of Chemical Engineers, December 3rd, 1914.

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PAINTING DEFECTS

Their Causes and Prevention

WHEN a defect in painting occurs, there are two different attitudes in either of which a person may place his mind. One is to assume that the defect is inherent in the paint used, and the other is to assume that the defect is due to an improper use of the paint. This difference in attitude of mind is not imaginary; it is so real that it seems very desirable that this difference should be explained and amplified.

The principal cost of any painting job is labor, and yet, when in the attitude of mind first mentioned, if a paint goes wrong one will condemn the materials used, whereas in the other case he will be inclined to hold that the most costly factor is the one that is probably responsible. It is easier to blame paint materials than it is to blame workmanship. Materials are tangible; workmanship is intangible. To some extent materials can be examined even long after they have been applied, but there are few means of recording satisfactorily what the workman has done. Every manufacturer of paint feels more or less that if his paint were properly applied it would give perfect satisfaction. Every user of paint is inclined to feel that if he could only get the right materials he would be quite sure that he could always do good work.

It would appear that perhaps in most cases the manufacturer is inclined to take one of these two attitudes of mind and the consumer the other, but this is not necessarily the case. Some manufacturers are wedded to certain beliefs with regard to materials, which, judging from their advertisements, one would be inclined to think fool-proof, and some few consumers blame their workmen when things go wrong without thought that the materials used may be at fault.

Without attempting to judge of the relative value of either attitude of mind, as so much has been written connecting painting defects with materials used, the writer proposes in this paper to take the opposite attitude and to treat of paint defects, their causes and prevention, not with the idea of connecting these defects to any appreciable extent with the materials used, although he will have to diverge from this rule to a slight extent, but principally to give you the results of a great many years of study of this subject from this standpoint, and to show how paint defects may in many cases be corrected without radical change in the materials used.

In studying a paint defect from the attitude of mind which is adopted in this paper, one cannot, of course, ignore the materials used, but one can seek to find out to what extent such a defect may be the result of the condition of the surface painted, the proportioning of the materials, the application of these materials, the time allowed between coats, etc. From this attitude of mind, all of these factors, and others similar thereto, are included in the general term "application." In studying a paint defect along this line, one must use his reasoning powers conscientiously and scientifically. To obtain an intelligent conclusion, he must study many defects; he should furthermore be able to reproduce experimentally the defects being considered before he can reach a positive conclusion as to their causes and cure. It must not be assumed that the writer can explain all paint defects. He makes no such pretentions. But in so far as he is able to speak positively in any case, it will be because he has been able to reason out the cause of the defect, and in most cases he has been able to reproduce the defect experimentally.

A word must be said here in regard to the proper use of painting tests. Such painting tests, in so far as they are of a controversial nature, have not appealed to the writer. The real value of painting tests lies in the information they furnish—in the ability they give the student to classify painting results, whether good or bad. The idea that paint materials can be tested out and their merits determined by a few panel painting tests is, in the opinion of the writer, generally unsound. But if such tests are to be conducted, they should be along lines entirely different from those which have heretofore been pursued, with one or two striking exceptions. The painting of panels indoors and then exposing them to the weather, and from such tests endeavoring to reach conclusions, favorable or unfavorable to certain paints, as the case may be, without prior thereto having determined that the method of testing is a fair representation of what actually occurs in practice, is an unsafe method to follow. To illustrate this by a parallel case, no chemist would dare to adopt a method of analysis or test that had not been checked up by analyzing or testing mixtures of known composition.

One of the exceptions to which reference should be made is the North Dakota tests. There Professor Ladd is not satisfied with painting panels and exposing them to the weather, but he also has had a number of houses painted following ordinary practice. In the case of the North Dakota tests, there are actual painting jobs done which serve as a check upon the panel tests conducted under his direction.

Another striking exception is the painting tests on the Havre de Grace Bridge, where the paints were applied both to the bridge proper and to the special panels erected along the side of the bridge. In all cases, if the panels do not confirm the actual service tests, they must be considered only as of secondary value. They have value—but only for the information they give.

This aspect of the subject has been driven home to the writer by the study of many thousands of tests which have been conducted under his direction. He has come to the conclusion that it is very difficult to make a panel test of paint materials which will give results which correspond to the results obtained with those same materials in actual use. The writer did not believe this at one time and was inclined to take issue with the statement of experienced paint manufacturers who said that panel tests were of little value as showing the merits of materials when in actual use. A little consideration will, however, show the difficulty of preparing panel tests that will be conclusive as to the merits of paint materials. I refer now to paint materials used for exterior painting. The usual way of preparing such tests is to get nice specimens of wood, to paint them indoors, to place them on racks between the application of each coat, and when they are thought to be thoroughly dry, to place them out-of-doors for exposure.

The objection to this method of painting is that we never bring a house indoors to paint it, unless it be a toy house, and the drying action of the under coats of paint is never the same indoors as it is outdoors. Indoors there is not the same circulation and abundant supply of air that there is out-of-doors. A great quantity of air is needed to dry paint properly for outdoor exposure. Panels painted indoors will not dry so hard as they will when painted out-of-doors. Panels that are stacked fairly close together will not dry so hard as panels spread out and given a great deal of air. We must not think that this applies only to the outer coat, for that will finally dry when it is placed out-of-doors, but we must remember that for out-of-door work all coatings are exposed to more or less rapid currents of air which dry them to a proper condition for durability.

A number of different methods have suggested themselves to the writer whereby panels painted indoors can be brought to a condition corresponding to outdoor exposure before the actual exposure is made. The writer has thought that perhaps a short heating of the panels after each coat has been applied, at say 120° F., might produce results that correspond to outdoor

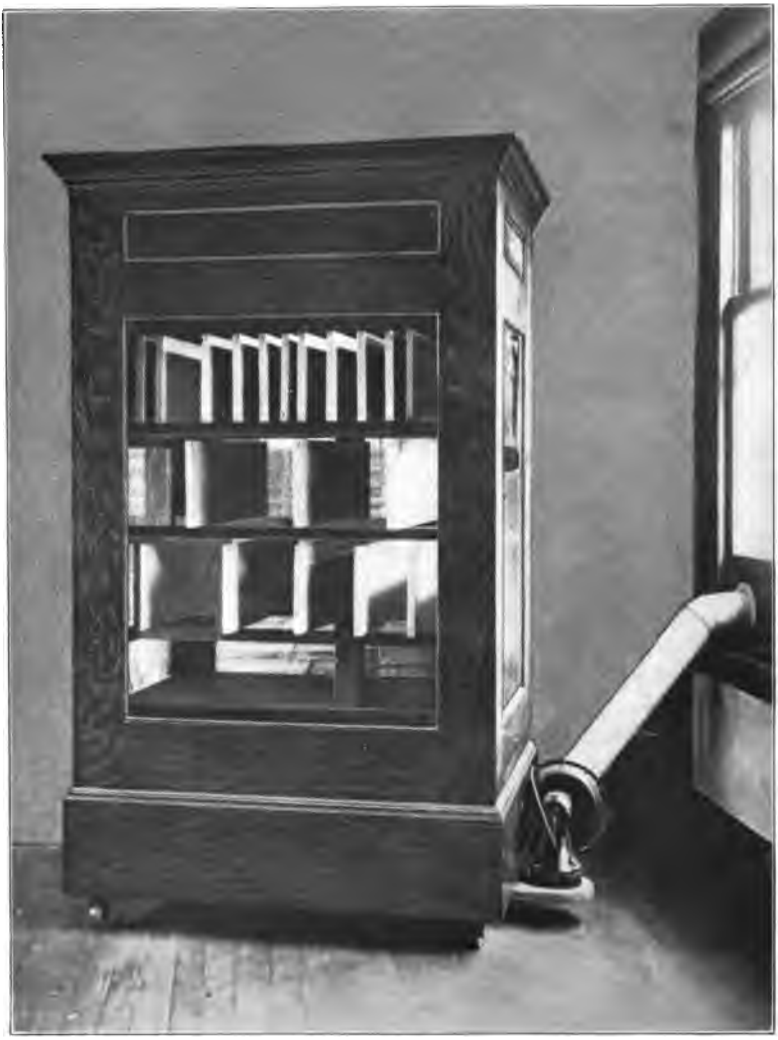

Figure 1

Test Board Drying Cabinet Supplied With Clean Out-of-Door Air.

exposure, or that by building a cabinet in which to dry the panels between coats, that cabinet to be supplied with fresh out-of-door air from a blower, he could thereby obtain results corresponding to outdoor exposure. A picture is shown here (Figure 1) of such a cabinet supplied by a blower with clean out-of-door air. But it is probable that both of these are questionable expedients and that the one way to get correct drying is by out-of-door exposure between coats under conditions where both air and light will be abundantly supplied.

But this is not the only point to which attention should be called with reference to panel tests. Most such tests tend to ignore the modification of composition of the various coats, which the experienced painter finds necessary in order to produce the best results. The principal modification would arise, of course, in the proportioning of the oil and thinner, but sometimes materials are added to paint for definite reasons, and the practical question will always arise whether it is best to add these materials to the first coat, the second coat, or the third coat, and what the quantities to be added shall be. In other words, panel tests to determine the value of paint materials should be conducted so as to obtain the very best results practicable with the materials used. This usually involves too much trouble and requires too much experience to satisfy the common demand for quick results.

With this explanation of the plan of this paper, a number of defects will now be considered in the double hope that some light may be thrown on their causes, and that the method of procedure adopted will serve as a help toward the solving of other defects, for the discussion of which the writer has not now the requisite time.

CHECKING AND ALLIGATORING

The first paint defect to be considered is that described by the general terms, "checking" and "alligatoring." It consists in the development of fine, interlacing lines on the surface of a paint, that is, lines embracing areas, which, if small, are called checks, and which, if large, have the appearance of alligator skin. It would appear that the phenomena of checking and alligatoring are closely related and are probably due to the same general cause.

Every varnish manufacturer knows the cause of the alligatoring of varnish. All general experience points to the conclusion that such alligatoring is due to the application of a hard varnish over a comparatively soft under coat. The alligatoring of varnish is particularly noticeable where cheap rosin varnishes have been used for the under coat. If varnish is applied over a grained surface, the ground of which is a yellow ochre paint which will not harden properly, the surface is quite sure to be alligatored. The reason that alligatoring occurs under these conditions becomes quite apparent with a little consideration. We will take a case of two coats of material applied to a smooth surface. The second coat is applied over the first coat as soon as the latter has dried sufficiently hard. The second coat then becomes dry. Now observe that while the first coat was sufficiently dry at the time the second coat was applied to permit the application of this second coat, it had not reached what may be considered a fit condition of dryness, that is to say, that if the second coat had not been applied and the first coat had been exposed to the air, the hardening which is due to oxidation would have continued indefinitely. By applying a second coat, this oxidation and consequent hardening of the first coat has been stopped, at least to a very large extent, but the second coat on the other hand, can keep on oxidizing and hardening indefinitely, just as the first coat would have done if the second coat had not been applied over it.

Now we know that nearly all oleo-resinous varnishes contain drying oils, which have the power of absorbing oxygen from the air and giving off certain

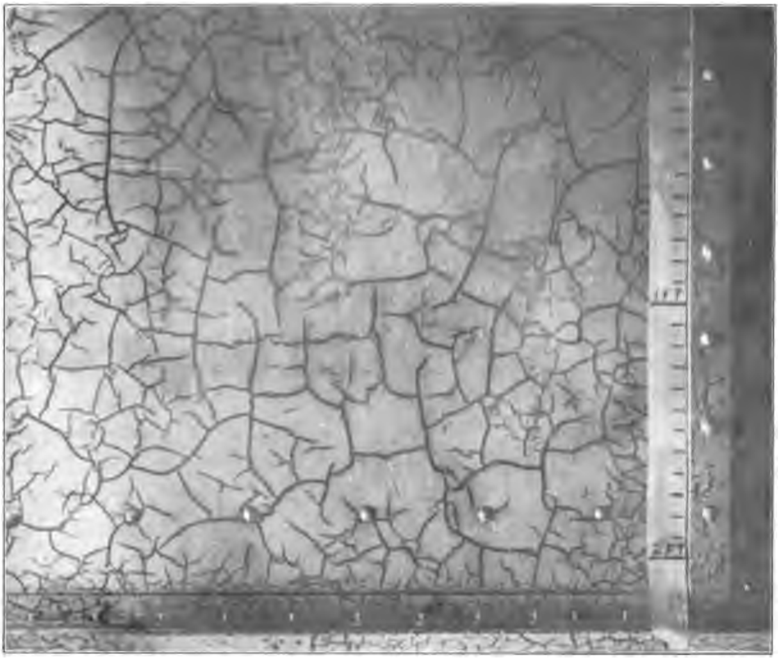

Figure 2

White Paint Over An Asphaltum Paint

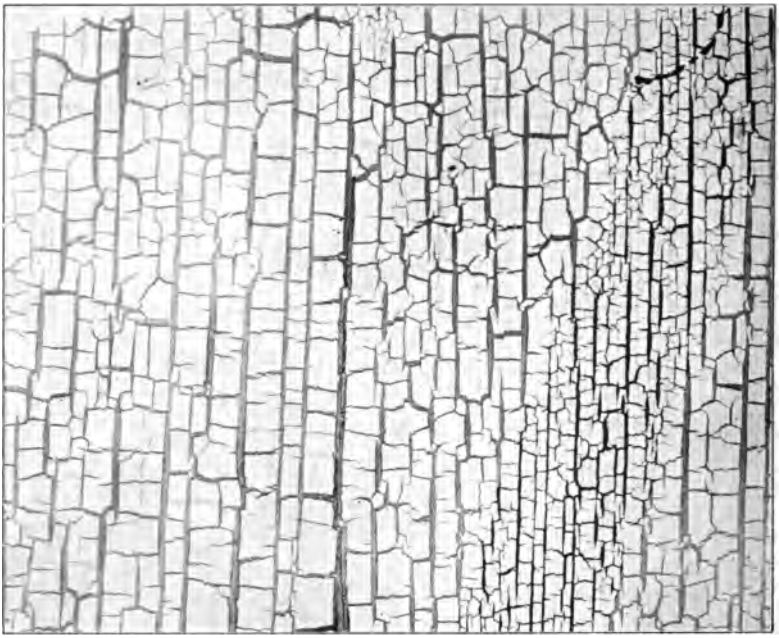

Figure 3

White Composite Paint Over Ochre Priming products of oxidation, and the longer a drying oil is exposed to the air, the more it becomes oxidized and the harder it becomes. We know also that there is a shrinking in volume during this operation of oxidation and hardening. We know that linseed oil, which is present in oleo-resinous varnish, increases in weight through oxidation in the beginning of the oxidizing operation until it has added to its weight up to 18%, but after this maximum increase in weight has taken place, there is a loss in weight due to the liberation of volatile compounds, which are carried away in the air, so that after a time a linseed oil film may reach a weight very close to that which it originally possessed. During these changes, the specific gravity of the linseed oil has increased, from which we must conclude that there has been a reduction or contraction in volume. All this has been demonstrated by the investigations of Prof. A. H. Sabin.

We can readily see how in the case of one coat of varnish placed over another, under conditions in which the first coat has not had a sufficient chance to thoroughly harden before the second coat is applied, the second coat on drying will contract and decrease in volume, while the first coat will remain practically unchanged in its volume and in its degree of hardness.

Now in all cases the outer coats of varnish and paint tend greatly to shrink in volume and to become progressively harder and more coherent, thus producing two possible effects. One of these possible effects is the rupturing of this outer coat with consequent alligatoring or checking. The other possible effect is that the outer coat becomes thinner without rupturing.

Which of these effects occurs depends upon the under coat. If the under coat is soft, the outer coat, in oxidizing and shrinking, will draw up and slip over it with consequent rupturing. If the under coat is sufficiently hard, the outer coat does not slip over it and simply becomes thinner by shrinkage, and no rupturing occurs.

This is the general explanation of the alligatoring of varnish and paint. It is also shown whenever a paint is applied over another paint that inherently will not dry hard, as in the case of a harder paint applied over an asphaltum paint (see Figure 2) or in the case of a harder paint applied over a yellow ochre paint (see Figure 3). Very extreme examples of checking or alligatoring occur where a non-volatile mineral oil has been used in an under coat.

This explanation is one that is quite generally accepted, although there may be minor points on which there is disagreement. Now, if this is true, in what way does checking differ from alligatoring? From the writer's experience, the causes of checking are identical with the causes of alligatoring, and he has experimentally produced a series of paint defects beginning with very fine checks on one side, and ending up with very large alligatoring on the other side. (See Figures 4 and 5.) If alligatoring takes place, it simply means that the under coat is relatively much softer than the outer coat. If checks occur, it means that this difference in the hardness of coats is not so great as in the case of alligatoring, but the difference is in degree, not in kind.

In order to avoid checking and alligatoring, it is best to seek to have the under coats as hard as is practicable, and to have these coats, relatively speaking, much harder than the outer coats. This is the practice in coach and carriage painting, where very little oil is used in the under coats, and as we know coach and carriage painting is perhaps the best type of painting there is. Now in the case of house painting, suppose we have checking and want to avoid it, how shall we proceed? The answer is inevitable. We must so modify our under coats as to secure a hardness sufficiently greater than that to which the outer coat will attain, and then checking will be avoided. To make the under coats sufficiently hard, various methods can be adopted.

The writer would now like to illustrate this matter

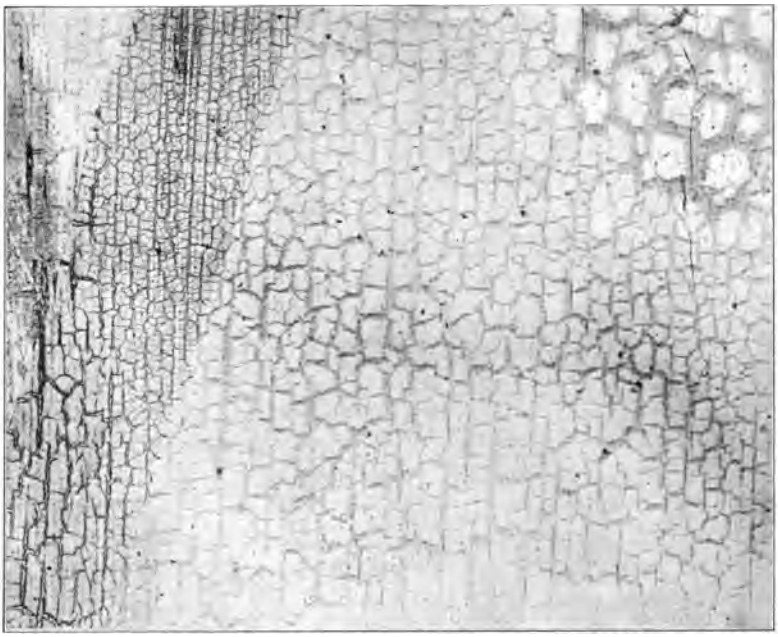

Figure 4

Composite Paint Over Oily White Lead Priming

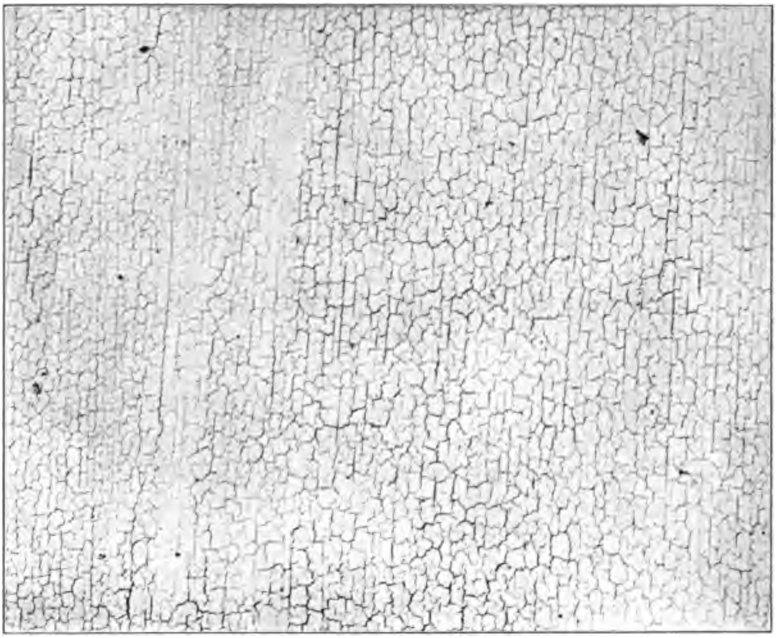

Figure 5

White Lead Paint Over Ochre Priming

by referring to some experiments which he has conducted. Realizing the limitations already referred to as inherent in panel tests, but still believing that they give information of possible value, he had a number of panels painted with white lead, one of which was ordinary white lead alone, and others containing varying percentages of acetate of lead. I show here three photomicrographs (see Figures 6, 7 and 8), the first with no acetate of lead in it, the second with 1%, and the third with 5%. You will notice that the white lead with no acetate of lead, shows very marked checking, while there is practically no checking in the case of the white lead containing 5% of acetate of lead.

Now I must repeat that I do not consider any of these panels fairly representative of good practice. All of these panels were dried indoors, and it is fair to assume that the under coats did not reach that maturity before exposure that they would have reached if the drying had been outdoors. This seems to me to be a general defect with panels, the under coats of which have been dried indoors. Nevertheless, these tests point in a certain direction and are evidence of the soundness of the view which I have advanced, for here clearly the acetate of lead has acted as a hardening agent on the under coats. It is true that the acetate of lead was used in the outer coat as well as in the under coats, but this does not affect the explanation we give of its action, for the hardening effect was relatively greater on the under coats than on the outer coat. These tests are neither an argument for nor against acetate of lead in white lead—they are simply evidences of the idea advanced.

There is one caution I must make here against assuming that in all cases checking is an unmixed evil. I am convinced that in some cases checking is the lesser of two evils, one of which is necessary. You can readily imagine a paint film of so great tensile strength that it will under no circumstances check. Now with the expansion and contraction of the foundation on which such a paint film is applied, trouble is apt to ensue, for if the foundation expands or contracts more than the film, the latter is sure to break loose, and the result is scaling. This, indeed, would be a more serious defect than checking, and the competent painter must use his judgment in some few cases as to whether he would sooner run the risk of a little checking or take the chance of a more serious trouble.

J. Cruikshank Smith, an English writer, in his little book on "Paint and Painting Defects," thinks that the terms checking and alligatoring, which he says are of American origin, are unnecessary terms, and it would be better to describe them as cracking. Cracking, however, as the term is used here, involves parting of a paint film right through to the surface painted. He says in his book, "Very often it (cracking) is caused by the final coat being less elastic than the under coat, or again, the last coat may have set too quickly, or may have been applied before the previous coat was quite hard."

All this is in line with what we have said before, if we understand that Mr. Smith is referring to the cracking of the outside layer or layers of paint. In regard to varnish, he also says: "This (cracking) is due in the main to causes similar to those which govern the cracking in paints or enamel." Speaking of graining, he also says: "As a rule, graining cracks on account of the graining color lacking elasticity, or because it has not been modified to suit the ground. If the ground is too oily, the application of the graining color may soften the ground, and unequal expansion and contraction, as between the color and the ground take place. Cracking will also be induced if the varnish applied over the graining color is too hard and non-elastic."

Now, understanding the causes which produce checking and alligatoring, let us see how they can be avoided, going into the matter a little more in detail. Let us direct our attention more particularly to house

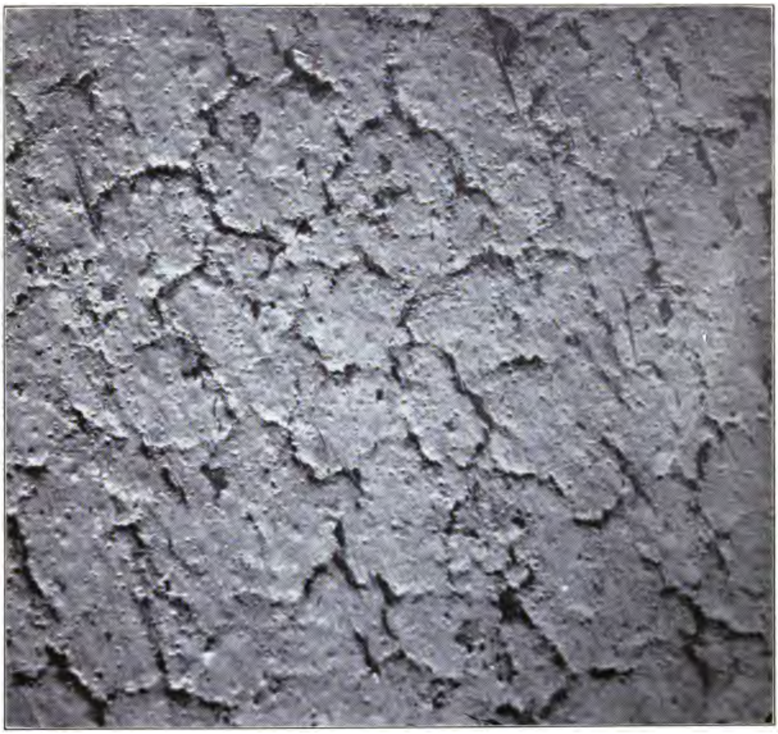

Figure 6 (Magnification x 8)

White Lead Paint Without Addition of Acetate of Lead

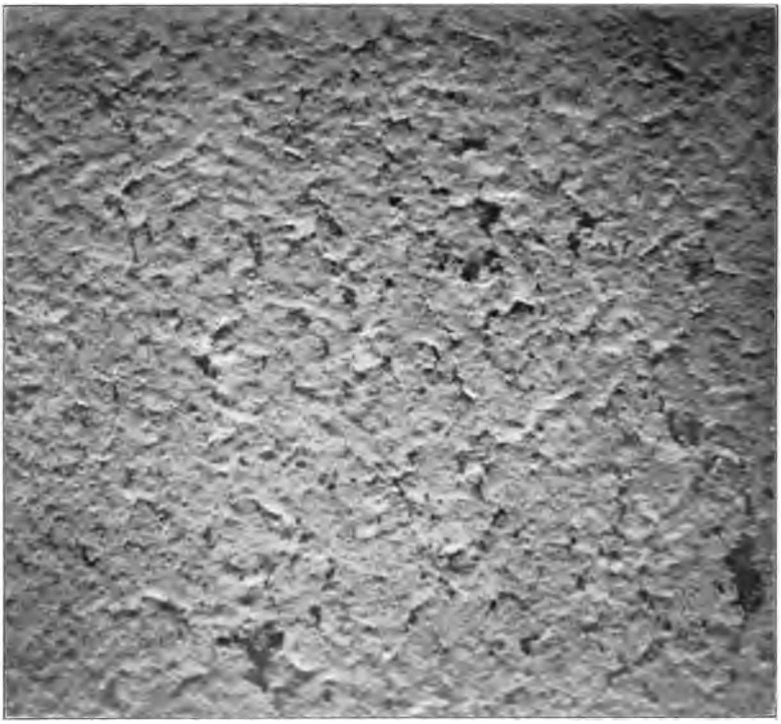

Figure 7 (Magnification x 8)

White Lead Paint With 1% Addition of Acetate of Lead painting, with which the writer is more familiar. We will assume that the work is to be three-coat work. We have, in the first place, a priming coat, the main purpose of which is to fill the pores of the wood and to produce a proper foundation for subsequent coats. We have over this a body coat, whose function is to supplement the priming coat and to hide the surface painted. We have finally the finishing coat, which supplements the body coat in that it gives hiding qualities to the paint and also gives the finish that is desired. Reversing our line of thought and starting with the finishing coat, we find that the under coats are for the purpose of giving a foundation to the finishing coat. The priming coat is the first foundation layer and the body coat is the second. Considering now merely the question of checking and alligatoring, it is evident from what we have already said that the priming coat and the body coat must, together, give a firm foundation for the finishing coat. How shall we obtain this firm foundation?

It is the writer's endeavor to avoid a discussion of the materials used, except where absolutely necessary. It is, however, important to point out here that no materials should be used in the foundation coats which will not harden sufficiently, or which cannot be made to harden by the addition of other materials. It is hardly digressing much from the policy which the writer has adopted to specify two materials which should not be used in the foundation coats. These are such oils or organic materials which have not in themselves the power of becoming sufficiently hard. To be specific, we would refer to all asphaltum, tar or bituminous materials. Furthermore, no mineral oil which is not completely volatile should be used. None of these products hardens sufficiently to give a good foundation coat. We must also exclude such resinous products as rosin oil which harden too slowly to give good results.

In all paints, a drying oil is used. The drying oil should have in a high degree the power of being oxidized into a solid substance. Linseed oil is the principal material used by painters for this purpose, and it should have this drying quality in the highest degree. The use of linseed oil substitutes which are liable to be deficient in this respect should be carefully avoided. It is important also that those pigments which retard the drying or hardening of priming coats should not be used in excess. This refers particularly to lampblack and yellow ochre. Other pigments of a similar nature will suggest themselves to you. On the other hand, pigments which assist in the drying and hardening of under coats should be used as far as is practicable.

As we have said, drying oils are essential in paints, but for the prevention of checking and alligatoring, no more drying oil should be used in the foundation coats than is necessary for the filling in of the pores by the priming coat and the proper binding of the particles of pigment together in the body coat. By so doing, two things are accomplished; one is that the natural hardness of the coating is increased by the increase in proportion of pigment, and the other is that, less oil being used, it takes less time to bring it to a fit condition for the reception of the other coats.

Probably the most important thing to do, in the avoidance of checking and alligatoring in the ordinary use of paints, is to allow as much time as possible between coats. We have already referred to the work of Professor Sabin, who has shown that the changes which take place in the drying of linseed oil result in the formation of certain volatile constituents, which should be given off before a paint reaches what has been called here a fit state of hardness. Just how long it is necessary to allow a paint to age between coats, it is impossible to say. If the weather is warm and dry, this fit state may be reached in a comparatively short time. If the weather is moist and cold, it may take a very long time. This suggests a difficulty in obtaining the best results when painting is done in cold weather, when paint dries more slowly. The writer

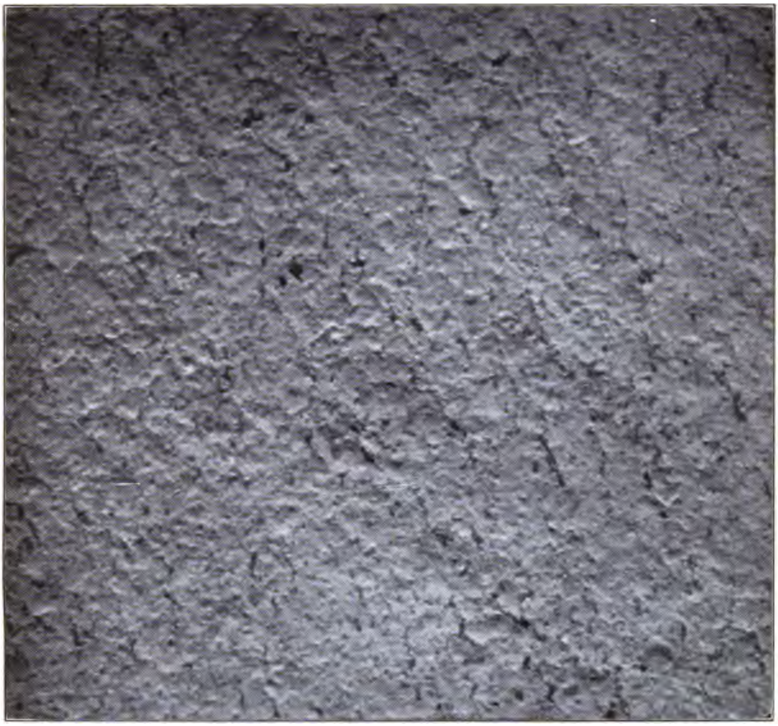

Figure 8 (Magnification x 8)
White Lead Paint With 5% Addition of Acetate of Lead

cannot give any time figures here, much as he would like to do so. The important matter, however, is that you should appreciate the reasoning which I have advanced, and with that reasoning in mind resist the tendency to haste in the application of paint, insisting that the best results can be obtained, particularly with respect to checking and alligatoring, by allowing ample time between coats for each coat to become thoroughly dry and hard.

CRACKING AND SCALING

The next defects which will be considered are those described by the two words, cracking and scaling. It would appear that these two defects are closely related, that is, that in many cases scaling naturally follows cracking. By cracking, we refer to the formation of hair-like lines on the surface, which an examination shows extend from the surface practically through the paint layer down to the foundation. In this respect, cracking differs from checking or alligatoring, which we have described as being superficial, that is as being connected with only the outer coat or coats.

In the case of cracking, the areas included by the cracks are usually relatively large, although not necessarily so. In case the painted object is wood, the cracks may be at right angles to or parallel with the grain of the wood. In discussing the question of cracking and scaling in this paper, we refer principally to the cracking and scaling of paint which has been applied to wood.

The fact that cracking starts sometimes at right angles to the grain of the wood and sometimes parallel with the grain of the wood, indicates that it is probably due, to some extent, to some action of the wood itself. It is desirable, therefore, that we should know something about the contraction and expansion of wood. Wood contracts and expands with cold and heat, just as most substances do. It is doubtful, however, whether this expansion and contraction with heat is a predominating factor as affecting cracking. This, however, is noticed: wood is a porous body containing at all times more or less free water or moisture. It has been found experimentally that in the drying out of wood, the greatest contraction takes place at right angles to the grain. Valuable information on this subject is given in Bulletin No. 10, U. S. Dept. of Agriculture, Division of Forestry. On page 37, it states:

"Since only an insignificant longitudinal shrinkage takes place (being commonly less than 0.1 inch per hundred), the change in volume during drying is about equal to the sum of the radial and tangential shrinkage or twice the amount of linear shrinkage indicated in the table.

"Thus, if the linear, average shrinkage of soft pine is 3 inches per hundred, the shrinkage in volume is about 6 cubic inches for each 100 cubic inches of fresh wood.

APPROXIMATE SHRINKAGE OF A BOARD, OR SET OF BOARDS, 100 INCHES WIDE, DRYING IN THE OPEN AIR.

	Shrinkage inches
1—All light conifers (soft pine, spruce, cedar, cypress)	3
2—Heavy conifers (hard pine, tamarack, yew) honey, locust, box elder, wood of old oaks	4
3—Ash, elm, walnut, poplar, maple, beech, sycamore, cherry, black locust	5
4—Basswood, birch, chestnut, horse chestnut, blue beech, young locust	6
5—Hickory, young oak, especially red oak	Up to 10

The reason for this difference in contraction parallel with and across the grain in the drying out of wood is easily understood with a little consideration. The structure of wood is largely fibrous, the fibres running mostly with the grain. Free water or moisture in the wood is probably located between the fibres. This water forces the fibres apart. As the water dries

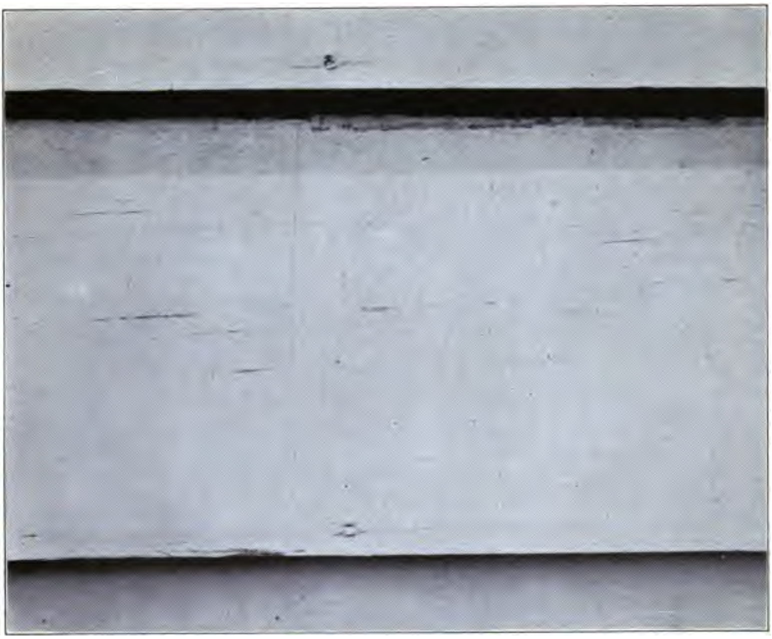

Figure 9

Cracking and Bulging of Paint Probably Due to Excessive Contraction of the Wood

out, the fibres come closer together, producing contraction across the grain. It would appear also that the variation of the amount of water in wood shows very little tendency to affect the length of the fibres, and so produce contraction and expansion parallel with the grain. It is probable that all have noticed the shrinkage of panels which usually takes place so as to expose the wood parallel with the grain, while very little wood is exposed at the ends of the panels. This drying out of wood apparently occurs even when wood has been painted or varnished, the indication being that even under these circumstances, paint and varnish films are slightly permeable to moisture and moist air. So much with regard to the contraction and expansion of wood as affected by its moisture contents.

Let us now consider what takes place in a paint film itself. I have already referred to the fact that linseed oil on drying shrinks in volume. It would appear, however, that the shrinkage of paint films is not due simply to the shrinkage in volume of linseed oil on drying. Wherever there is a chemical reaction between the pigments of a paint film and linseed oil, or any of the other paint constituents which chemical reaction results in the formation of new chemical compounds such as soap, there is still further contraction due to the condensation which takes place with the formation of these compounds. Unfortunately, we have no definite figures as to what this condensation or contraction amounts to. It probably differs with every reacting pigment, so that some pigments will produce a large contraction and others a slight contraction, while in the case of pigments which do not react chemically on the oil, there is probably no contraction due to this cause.

Now let us think of a paint having this quality of contracting due both to the oxidation of the oil and to the reaction of the pigment upon the oil, as applied to a wood which contains moisture. The wood dries out and contracts across the grain, while there is very little contraction with the grain; at the same time the paint contracts both across the grain and with the grain. If the contraction of the paint equals in all respects the contraction of the wood on drying out, there should be little tendency of the paint to crack. Wood, however, as we have shown, contracts mostly across the grain. Consequently, if the paint contracts across the grain less than the wood contracts, there will be a bulging and consequent cracking of the paint with the grain. (See Figures 9 and 10.) The reverse condition, that longitudinal cracks may occur due to the paint contracting more than the wood, is also possible but not probable. On the other hand, the contraction of the paint with the grain will not be compensated by a similar contraction of the wood, and cracks may appear, the lines of the cracking showing across the grain (see Figure 11). This is the rational explanation of cracking. It is assumed, of course, when cracking occurs, that the paint has very little elasticity, is very hard, and is high in tensile strength. The size of the spaces enclosed between the cracks is largely dependent upon the tensile strength of the paint film. If the tensile strength is high, the distance between the cracks will be greater than if the tensile strength is low.

Now what is the relation between cracking and scaling? Cracks, as we have referred to them, extend down to the wood. As soon as cracks occur, there is an opportunity for moisture to enter the wood. This moisture, entering by the cracks, travels under the paint film, exerts a pressure against the paint film, the bond between the paint film and the wood is weakened and scaling results.

Further on in this paper, blistering and peeling will be spoken of. It seems to the writer that there is a difference between peeling and scaling. Both are due to moisture forcing the paint film away from the wood. Peeling, however, is due to the presence of moisture under an unbroken paint film in the wood or back of

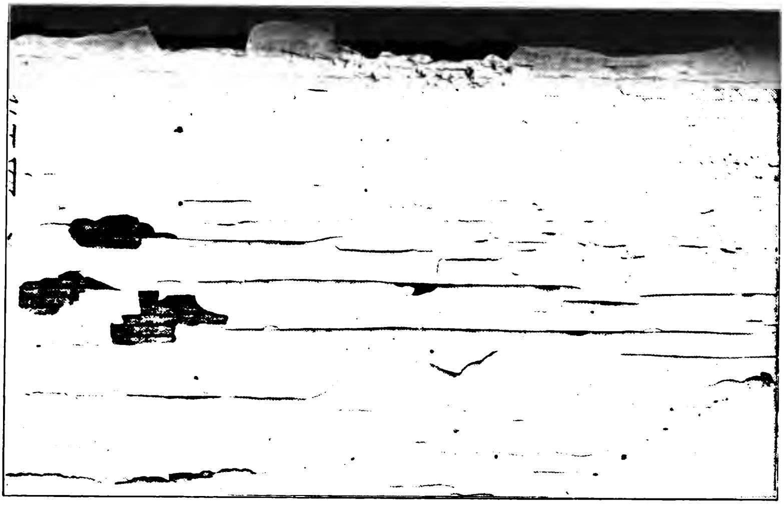

Figure 10

A Bad Case of Cracking Showing the Bulging at the Longitudinal Cracks

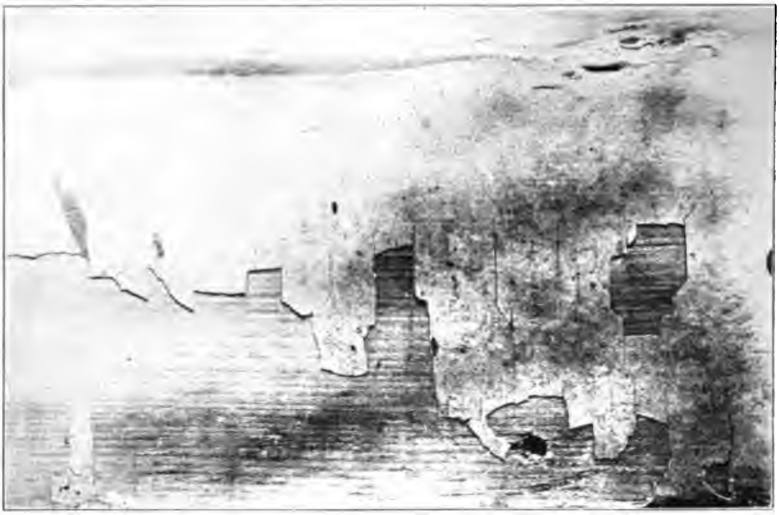

Figure 11

A Bad Case of Cracking and Consequent Scaling, the Cracks Across the Grain Being Characteristic the wood, which forces the paint away from the wood. But in the case of scaling, the moisture enters through the cracks and travels under the paint film, causing the scaling.

We now come to the question of the prevention of cracking and scaling. It is to be noted that, as a rule, cracking and scaling take place most often when the paint film is thick. It may not occur on a first painting job, but when the work is repainted, cracking and scaling occur. The reason for this is obvious. The thicker the paint film, the stronger it is, that is the greater its tensile strength, and it cannot conform as readily to the changes in the shape of the wood. One method of prevention, therefore, is to avoid the accumulation of paint coats upon a surface. If the surface needs repainting, as much of the old paint should be sandpapered off as is necessary, provided, of course, it is too thick, and the new coats of paint applied should be comparatively thin. This refers particularly to paints which are naturally inclined to crack and scale. It is obvious, of course, that those pigments, which give hard, strong and contracting coats, should be used only in moderation. Just what moderation is can only be determined by conditions. It is impossible for the writer to offer more definite advice than this. There are some cases, however, where the painter is in a dilemma. If he wants to prevent cracking and scaling, he can do this only by allowing a certain amount of checking. Reference has already been made to this difficulty. Hard under coats tend to prevent checking, but too hard coats generally favor cracking and scaling. Soft under coats favor checking, but tend to prevent cracking and scaling.

We must suggest also that cracking and scaling can be, to some extent, avoided by having the wood thoroughly dry and contracted before painting.

I wish I could explain here the scaling of paint on galvanized iron. I regret to say that all attempts at explanation have so far failed. I have found paint scaling on galvanized iron with every precaution taken to prevent it. Galvanized iron has been washed with acid, with alkalies, and with special galvanic primers, such as acetate of copper, etc., without, however, preventing scaling. The scaling on galvanized iron is evidently due to the impossibility of securing a proper bond. It is more apt to occur with hard or thick coatings than it is with more elastic and thin coatings.

BLISTERING AND PEELING

As already indicated, it is hardly necessary to say much on the subject of blistering and peeling. These defects are due to the water in wood forcing its way through the wood to the surface, and breaking the bond of the paint and forcing it away from the surface. Blistering is very apt to occur where moist, painted wood is subjected to heat, such as the heat of a radiator. Sometimes the heat of the sun is sufficient to increase the vapor pressure of the water enough to produce blistering.

Blistering and peeling are more apt to occur if a very impermeable paint is used. Painters sometimes complain that boiled linseed oil favors blistering. If this is so, it can only be due to the fact that boiled linseed oil gives a more impermeable paint. If one paint tends to blister more than another under similar conditions, it is probable that the paint which tends more to blister is the more impermeable. The one safe method of preventing blistering is to remove the cause, that is, the moisture in or back of the wood. In cold weather, wood may appear to be dry, and yet contain a great deal of moisture, which in a warm day will force its way to the surface. If one is in doubt as to the condition of wood for painting, the best practice is to allow considerable time after the priming coat has been put on before applying the body coat. It would appear in general that paint allows moisture to

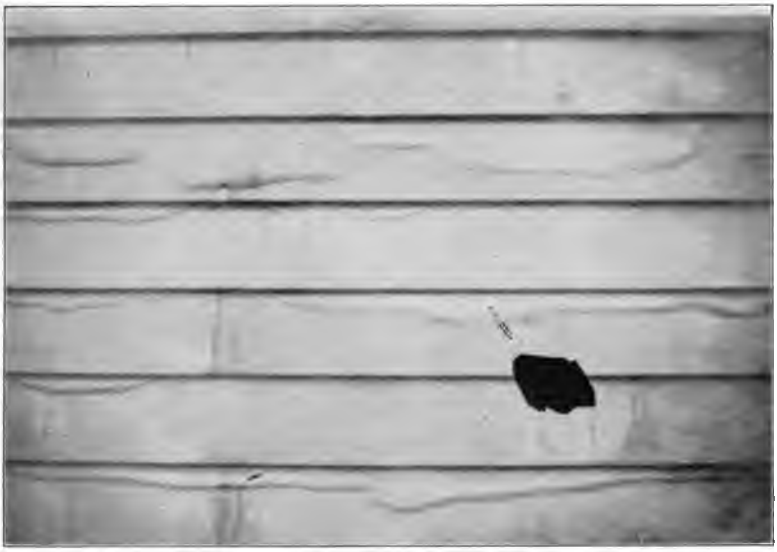

Figure 12

Blistering on Top Coat Only. The Blisters Are Full of Water

pass out through it to the atmosphere more than it allows moisture to pass the other way. This is probably largely due to the fact that we generally have more dry than moist weather. If a priming coat is applied in this way, it will allow the wood to dry out and to a certain extent will prevent the moisture in the wood from being increased from external causes.

The practice of applying backing paint to window frames, and in general on wood apt to become moistened on the inside, has for one of its objects the prevention of blistering and peeling.

Blistering on iron and steel is due to a different cause. Here it generally results from the formation of gaseous products under the paint, due perhaps to the corrosion of the iron, which forces the paint from the surface. Sometimes peeling will occur on enameled surfaces which have been painted without proper care being used to roughen the surfaces so as to produce a proper tooth. Sometimes peeling will occur when a paint has such rapid drying qualities, that, when applied over old work, the paint dries before the oil in it has had a chance to soften up and combine with the old paint surface.

There is another kind of blistering and peeling, to which I will refer only incidentally without attempting to explain it. Sometimes it has been found in the case of a recently painted house, that after a heavy rain storm, large blisters like those shown in Figure 12 make their appearance. These blisters are filled with water, the water being, as a rule, between the coats of paint. The under coats of paint are in sound condition, and it is impossible to conceive of the water having come from the back of the paint. The probabilities are that the water passed through the outer coating of paint by some system of diffusion and collected under it.

LOSS OF GLOSS AND CHALKING

The chalking of paint is one of those problems most difficult to solve. Perhaps in one sense, it should not be referred to at all in this paper. I say this for the reason that the reactions which produce chalking, so far as they have been explained by previous investigators and also by the writer, are purely theoretical. I am speaking of it, however, so that you will know that it has received proper consideration.

Chalking is connected with a loss of gloss which a paint undergoes, that is to say, the antecedent of chalking is loss of gloss. This immediately suggests that loss of gloss and chalking are produced by the same general cause. As to loss of gloss, we are pretty sure of its cause. Gloss is due to an excess of oil or binding material, which, lying over the particles of pigment, gives a smooth, even, glass-like surface. The binding material in paints, whether it be linseed oil or varnish, is an organic substance—a substance composed of carbon combined with hydrogen, oxygen, etc. Such organic substances as are used for the binding material in paints are more or less unstable—they are subject to fairly rapid destruction when exposed to the influence of air, moisture, and sunlight. Loss of gloss is due to this destruction, and it would appear that the chalking of paint is but a step further in this destructive action, whereby the binding material is destroyed, and the pigment becomes loosened on the surface. It may be that, in some cases, this destruction of the binding material is superficially accelerated by the pigment or pigments used. However this may be, the proximate cause of chalking is connected with the destruction of the outside binding material in a coat of paint.

Our description of the phenomena of chalking would not be complete if we did not refer to another type of chalking which occurs in the case of certain pigments which are physically unstable. Such pigments appear to change under the influence of moisture from the state in which they were used into a different state, and in these circumstances are apparently dissolved out of the paint by moisture, and deposited as a film over the outside layer. I refer here particularly to the chalking which takes place in the case of basic sulphate of lead, which is a fire process pigment and seems to be peculiarly susceptible to the influence of moisture. I say nothing in derogation of this pigment and would not mention it at all if it were not necessary to make clear the nature of the chalking which occurs at times in its use.

To make my meaning clear, I would explain that basic sulphate of lead is one of those pigments which must be kept thoroughly dry, because if this is not done, it will deteriorate very rapidly. We all know that sulphate of lead made by wet chemical processes has very little tinting strength. This is due to its crystalline and relatively coarse structure. It would appear that basic sulphate of lead, when treated with water, changes in structure so as to approach the characteristics of sulphate of lead prepared by the wet process. Also that basic sulphate of lead, when used in paint, is soluble to such an extent that it becomes changed physically and is dissolved and deposited in its changed form on the surface of the paint. Such a change may or may not take place along with the decomposition of the oil on the surface, such as takes place in the case of ordinary loss of gloss and chalking. It is very often found, however, with basic sulphate of lead paints that, if the fine bloom which shows more strikingly in tinted paints is removed, the paint is in excellent condition underneath.

Another phase of this question should also be considered. If an elastic paint chalks, it may be that the particles of loosened pigment will be held loosely on the surface, and not be washed away by rain to as great an extent as would occur in the case of less elastic paints.

Whatever the cause of chalking may be, it is objectionable, principally because of the tendency of the pigment to come off when touched. There is no question but that it is objectionable from this standpoint. There is another point, however, which must not be overlooked. Paint decay is of many kinds, and one of these many kinds is inevitable. The experience of the users of paint points to the conclusion that most painting jobs will not last in good condition longer than three or four years. This being so, a certain amount of chalking, that is, loss in thickness of coating, is the least objectionable form of decay. For if this loss in thickness does not occur, the result on continued repainting will be the production of so thick a coat of paint that scaling is apt to follow. The fact already mentioned that scaling is more apt to occur with thick layers of paint than with thin is well verified by experience. Chalking, as it ordinarily occurs, has this further redeeming quality. It nearly always leaves on the surface a roughness, usually called a tooth, which is favorable to repainting.

For the prevention of chalking and loss of gloss, to the extent that this is desirable, we can offer only qualified suggestions. It is evident that what is desired is a vehicle which can be used on the surface of paints that will be more permanent, that is, less destructible than what is ordinarily used. I regret that there is no such material that can be unqualifiedly recommended. I am quite sure that a linseed oil, which has been bodied by blowing or real boiling, would help in this respect, but here again another danger confronts us. Such an oil, to be satisfactory, should dry sufficiently hard so that it will not be inclined to absorb dirt. The writer remembers using such an oil a number of years ago, with great expectations, but while the oil was less destructible, it remained so soft that dirt readily attached itself to the surface. Sometimes varnish is used in a finishing coat, but so far as I know, this has not prevented loss of gloss or chalking. All that can be said, therefore, is, that if chalking is a defect, it is not an unmitigated evil. Nor is it one that can readily be avoided without other more serious defects arising.

Figure 13

Showing the Water Mark Due to Washing Near the Lower Edge of the Board

You will observe here that I say this with full regard for the plan adopted, that I am not discussing any farther than is necessary for the purpose of this paper how defects may be corrected by changing the materials used.

WASHING

The washing of paint is characterized by the surface of the paint giving up certain water-soluble substances. This is noted in the following ways: The surface, when moistened, rubs up like soap. There is a collection of washed-down pigment at the footings of columns and similar conspicuous places. There are also noted on the ceilings of porches brown spots consisting of substances which have been dissolved out of the paint by moisture, and when the moisture has evaporated, these spots are left, like miniature stalactites or pimples. Apparently, washing takes place when a paint contains water-soluble compounds or when water-soluble compounds are formed either through a reaction of the constituents of the air upon the pigment or a reaction between the pigment and the binding material. Usually a surface that shows washing is found to be in excellent condition underneath. Washing very seldom takes place until loss of gloss occurs. Sometimes, as in the case of the picture shown here (Figure 13), the dissolved material will run down near to the edge of a clapboard and, on evaporating there, leave a water mark or stain just above the edge.

Washing is less common in the country than it is in large cities, probably due to the greater quantity of sulphur gases present in urban atmosphere.

For the prevention of washing, omitting any reference to the avoidance of the use of those pigments most inclined to wash, the only thing that I can recommend is what I have already recommended in the case of chalking. As washing does not occur to any appreciable extent until the gloss of the paint has disappeared, the best method of prevention is to be found in such steps as can be taken to preserve the gloss as long as possible. Washing is apt to give the surface an unsightly and streaked condition, which can usually be quite readily corrected by the application of clean water.

DISCOLORATION

The discoloration of paint is a very large subject, and can be handled in this paper only to a limited extent. We will not discuss the changes in the color of pigments, which are more or less directly connected with the pigments used, such as the natural tendency of yellow and red paints to darken or certain blue paints to fade. These are mostly due to internal changes in the pigment itself. Our subject divides itself naturally into the following heads: Spotting, such as when tints turn white in spots; Discoloration Due to Yellowing Out-of-Doors; Discoloration Due to Yellowing Indoors; Discoloration Due to Dirt; Discoloration Due to Mildew; Discoloration Due to Sulphur Compounds.

SPOTTING

In the spotting of paint, the following characteristics are to be noted. The spots, which may be small or large, are much lighter in color than the remainder of the paint. Such spots show greater chalking than the body of the paint. Moistened with linseed oil, the spots return to practically the original color of the paint, indicating that there had been no destruction of the tinting material, and indicating also that at these spots there had been some excessive destruction or loss of the oil which was originally present. Spots are very apt to appear along the edges of cracks in wood. Sometimes they appear over and around putty, indicating the location of nail holes.

The explanation which I would offer as to the most common cause of spotting is that at the points where spotting occurs, the wood was not completely filled by the priming or body coats. Spotting occurs earlier in two-coat work than in three-coat work. It would appear that, although a paint may be thoroughly dry, if portions of the surface painted are not fully satisfied by the priming coat, some of the oil in the subsequent coats may be absorbed by these spots. It may be also that in such a case there is a more rapid internal oxidation and destruction of the oil due to the excess of air under and back of the spotted places. Whatever the exact features of the cause may be, the remedy is clear. Spotting is to be avoided by the proper filling of the pores of the wood, and by allowing sufficient time between coats for weaknesses to develop that can be corrected by subsequent coats. Spotting will be avoided, to some extent, by the competent workman using a stiff brush for the under coats, thereby forcing the paint into the wood.

There is another kind of spotting due to the spattering of lime on wood before it is painted, which lime spots work through the paint and, by destroying the oil, show on the outer surface.

DISCOLORATION DUE TO YELLOWING OUT-OF-DOORS

The yellowing of paint out-of-doors applies mostly to white paint. The term yellowing is a sufficient description of what takes place. There are two known causes of this kind of yellowing. One is the presence of heavy mineral oil, and the other is the presence of alkalies or alkaline materials. The yellowing of paint due to the presence of heavy mineral oil, appears as follows: A mixture of linseed oil and mineral oil if exposed to the air in thin layers, soon becomes clouded, due to the oxidation of the linseed oil and its separation from the mineral oil. The mineral oil remains practically unchanged. If used in all coats of paint on wood, it exerts a solvent action upon the wood painted, bringing to the surface the gums and other soluble, organic material present. Mineral oil itself yellows on oxidation.

The yellowing of paint, due to the presence of alkaline materials, is explained in this way. Linseed oil soap, which is formed by the action of alkalies upon linseed oil, tends to become a very dark orange on exposure to the air. Linseed oil of itself tends to bleach out during oxidation and become more nearly white. If alkalies are present the oil becomes very much darker, and paint in which the pigment is surrounded by an oil which has undergone such a change will appear yellow.

The prevention of the yellowing of paint out-of-doors, in so far as it is caused in these two ways, is by the avoidance of the use of heavy, non-volatile, mineral oils in paints, and also the avoidance of the presence of alkaline materials. By alkaline materials we refer to those materials which form soluble soaps with linseed oil, such as soda ash, borax, silicate of soda, etc.

DISCOLORATION DUE TO YELLOWING INDOORS

The discoloration of paint due to yellowing indoors is a common phenomenon. It has the following characteristics: The yellowing takes place in the dark, and if the object painted can be exposed to the sunlight, the yellowing disappears. In the case of tints, they are changed from the color originally applied. Blue becomes green, and red, if not too deep, an orange, etc. The cause of the yellowing of paint indoors is variously explained, but the one explanation which seems most satisfactory is this: ammonia is more or less present in the atmosphere. Ammonia turns white paint yellow. Ammonia is an alkali, and this action of ammonia is similar to the action of the fixed alkalies referred to in the yellowing of paint outdoors. Ammonia may be used in manufacturing establishments, where yellowing occurs, as in the case of ice-plants. It may be used for cleaning purposes around the premises painted. It may even be generated from the glue size applied to plaster walls, which have not sufficiently matured. It is well known that glue, which is a nitrogenous body, under some conditions, gives off ammonia in the presence of alkalies and alkaline earths. Gloss paints are more apt to yellow than flat paints. Linseed oil yellows more than poppy oil. It would appear that the yellowing of linseed oil, as affected by the pigment used, depends more upon the degree to which the oil is exposed to the action of the atmosphere. The pigment protects the oil more in some cases than in others. The more impermeable paint is less affected by ammonia. A thin coating of varnish over a paint or a little varnish in a final coat will often prevent serious yellowing. The prevention of yellowing, therefore, is all summed up in these words: Have good ventilation, good light, avoid the presence of excessive quantities of ammonia in the atmosphere, and protect the paint as far as practicable by varnish coatings wherever such a treatment is necessary.

DISCOLORATION DUE TO DIRT

This kind of discoloration of paint, especially white or nearly white paint, is one for which the painter sometimes feels justified in claiming he is not to blame, because the dirt came from outside sources over which he had no control. This attitude is perfectly proper up to a certain point. There still remains the fact, however, that paint will sometimes become dirty more rapidly than exterior conditions would seem to warrant, and to this extent it is a fault of the paint. The dirt, which may accumulate on and stick fast to the paint comes from smoke, ordinary street dirt, the organic matter from growing plants, such as pollen, and the organic matter from decaying plants. Dirt can be carried great distances by the wind and disfigure paint. Discoloration of this kind will occur sometimes in the most inaccessible places. Dirt will collect on roofs, and in the case of storms, may be washed down over paint and become attached to it. The examination of paint at very high altitudes greatly removed from smoky chimneys may still show a deposit of smoke and coal dust. The quantity of pollen that is liberated from trees, grasses and many flowering plants is enormous. The fertilization of the seed is dependent upon the wind carrying the pollen and distributing it so that perhaps one particle of pollen in one hundred million is actually serviceable, while the remainder is scattered in all directions. A great deal of this pollen is sticky on its surface. Under the microscope, it is shown to possess various forms usually more or less spherical. Decayed pollen massed together appears black, but under the microscope it is observed to be quite translucent and yellow. The conditions favorable to dirt becoming attached to paint are softness and elasticity, conditions which the painter naturally thinks are the best for the paint. Fresh paint is more apt to become discolored by dirt than old paint, simply because fresh paint is more elastic and stickier. After a rain nearly all paint becomes softer than it was before the rain. Under such circumstances if conditions are favorable, as in the case of the quick drying up of the soil, dirt from roads, etc., may be blown against the paint and remain attached. Some have attributed the increased tendency of paint to become discolored to the increased use of the automobile, which raises clouds of dust on dry days.

The obvious method of the prevention of the discoloration of paint is the use of harder coats, obtained either by cutting down the amount of oil in the paint, or by the use of those pigments which tend to harden the paint. The practical painter must choose between these methods. And here again he may be confronted with the same dilemma, in other words, he may jump from the frying pan into the fire. If by adopting the practice of working towards hard coats of paint he prevents discoloration, he may run into the trouble of cracking and scaling.

A curious instance of the discoloration of paint has been brought to our attention in New Orleans. There they are troubled a great deal with mildew to which reference will be made later, but in addition to this they are troubled a great deal with the dirtying of paint due to dust. New Orleans, within the last ten years, has introduced a system of drainage which has resulted in the earth becoming very much dryer than it used to be. During the dry season the soil is dry to a greater depth than formerly. Experiments conducted at New Orleans indicate that the quality of the linseed oil used there affects considerably the tendency of paint to become discolored both from mildew and from dirt. It is found, for instance, that La Plata linseed oil, when used in paint in New Orleans, occasions the discoloration of the paint more than North American linseed oil. This is clearly due to the fact that North American oil when used in paint gives a harder coating than does La Plata oil. La Plata oil has a lower iodine absorption, and it would appear fairly conclusive that only the best quality of linseed oil should be used there and in similar places, and furthermore that all linseed oil substitutes made from the semi-drying or non-drying oils should be avoided.

DISCOLORATION DUE TO MILDEW

Discoloration of paint on account of mildew is rather uncommon in the North, but is fairly common in the South. Mildew is a fungoid organism propagated by fine spores, which when they develop form a fine network of threads. These threads while black to the eye are more or less transparent under the microscope. It would appear that in some cases mildew exists in the wood itself before painting. In other cases its filaments may penetrate the paint and enter into the wood. The ordinary pigments used do not seem materially to prevent the growth of mildew. It would appear that mildew grows better in elastic paints than it does in hard paints, and that moisture and shade are favorable to its growth. Experiments indicate that mildew is killed by the presence of very small quantities of mercury compounds and that a minute percentage of mercurous chloride added to paint will prevent mildew.

We have already suggested the methods which can be used for the prevention of mildew. Mildew is prevented to some extent by the use of paint which forms a hard coating and by the use of the best quality of linseed oil. It may also be prevented by adding to the paint a small percentage of mercurous chloride.

DISCOLORATION DUE TO SULPHUR COMPOUNDS

Discoloration due to the presence of sulphur compounds occurs with those paints containing lead pigments. It appears as a brownish or grayish, metallic, continuous film over the surface of the paint, which film is sulphide of lead and may be readily destroyed by peroxide of hydrogen. Sometimes this discoloration is due to the intentional or accidental presence in a paint of small amounts of sulphides of the other metals, particularly sulphide of zinc, which may be contained in lithopone to the extent of 30 per cent. The frequent and common use of lithopone in recent years has led to a number of cases where lithopone has been used accidentally with lead paints with resulting discoloration. It is possible that the presence of lithopone in such cases may come from the use of pails for lead paints which pails had previously contained lithopone. Sulphide of zinc in lithopone does not always react with lead pigments to produce sulphide of lead. The danger of such a reaction taking place, is, however, so great that extreme caution should be used against it. In moist places lithopone is more apt to react on lead compounds than in dry places.

The discoloration of lead compounds due to sulphur compounds in the air is not as common as one would be inclined to believe from what has been said upon the subject. The only chemical compound in the air which will produce sulphide of lead is sulphuretted hydrogen, which is given off from manure and sewage, and is sometimes found around coal mines and oil wells. Discoloration produced from sulphuretted hydrogen in the air is not usually permanent. Very frequently it will appear in a dry season and then will entirely disappear after a good rain storm. This is due to the fact that sulphide of lead is rather unstable and tends to oxidize to sulphate of lead.

There are indeed considerable amounts of sulphur compounds in the air of cities and around factories. The sulphur compound most commonly in the air is, however, sulphurous acid, which does not react upon the lead to produce sulphide of lead. Sulphuric acid is also present. Sulphurous acid reacts on lead to form a white, insoluble sulphite of lead, which probably oxidizes under ordinary conditions to sulphate of lead, also white. The action of sulphurous acids on lead compounds forming sulphite of lead is paralleled by a similar action upon other pigments to form sulphites, as in the case of the formation of zinc sulphite which readily oxidizes to zinc sulphate, to the formation of which the washing of zinc paints is largely due. Sulphuric acid in the atmosphere forms sulphate of zinc directly.

The presence of sulphur compounds in the air is generally objectionable, and in most cities endeavor is being made to prevent this annoying condition. This is being done by improved sewage systems, high chimneys, and central power plants, as well as by the introduction of hydro-electric power, which avoids the burning of coal. Sulphurous and sulphuric acids are especially active in the corrosion of metals, and those pigments which tend to fix them, that is form insoluble compounds with them, are in this respect best for the preservation of metals.

There is only one method of preventing the discoloration of paints by the action of sulphur compounds in the air. That is to prevent the presence of such compounds. For the number of lead pigments which it is necessary for the painter to use is so great that it would seem impossible effectively to prevent discoloration in any other way.

OTHER DEFECTS

There are other defects, which could be touched upon in this paper, but it is already so long, and the main defects have been so completely treated that the writer hardly feels justified in extending its length.

CONCLUSION

The main purpose of this paper has been to consider the question of paint defects without reference, except to a minor extent, to the nature of the materials used. The writer has deliberately taken an attitude of mind which he acknowledges is not a perfect attitude. He admits that the materials used must be considered in the study of paint defects. At the same time as there has been so much attention given to the question of the effect of materials upon paint defects, with a neglect of the treatment of the subject followed in this paper, it has been deemed necessary to investigate exclusively the other side of the question, in order to more evenly balance the arguments upon the subject. The tendency to connect paint defects with materials has been too great. This paper will serve to some extent to counteract this tendency.

The practice of connecting paint defects exclusively with materials is a destructive practice. Our plan in this paper has been to present a constructive program. No paint material is perfect, but if it is to be commercially judged in comparison with other paint materials it should be judged at its best and not at its worst. It is the hope of the writer that some time in the future a new spirit will enter into the discussion of paint materials; that it will be the endeavor of all paint students to find the best way to use paint materials and if a paint material is in any way defective to find out how that defect can best be corrected.

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